Using Taped-Problems and Rewards to Increase Addition-Fact Fluency in a First Grade General Education Classroom

Kathleen B. Aspiranti, Christopher H. Skinner, Daniel F. McCleary, and David F. Cihak
The University of Tennessee, Knoxville

ABSTRACT

We used a multiple baseline design across math facts to evaluate classwide use of a taped problem (TP) intervention on first graders' digits correct per minute in a general education classroom. During TP, students attempted to respond to each math fact before they heard the answer on an audiotape. As problems were repeated, response intervals were varied and individual and group feedback and rewards were provided contingent upon improved performance. Across all 3 sets of problems, digits correct per minute increased following the use of TP. We discuss the efficacy of TP as an instructional (as opposed to remedial) procedure, practical implications for teachers, and areas for future research.
Keywords: classwide general education, first grade, math fact fluency, taped problems

Although a great deal of time in elementary school is allotted to mathematics (Porter, 1989), many elementary students fail to master math skills, including the ability to solve basic facts fluently (National Center for Educational Statistics, 2009; National Council of Teachers of Mathematics, 2007). Without sufficient knowledge of basic math facts, mastering advanced math tasks is difficult (Gagne, 1983; Hasselbring, Goin, & Bradsford, 1987). Furthermore, students who spend too much time and effort completing basic facts may have higher levels of math anxiety and attempt to avoid engaging in math-related behaviors (Billington, Skinner, & Cruchon, 2004; Cates & Rhymer, 2003; McCurdy, Skinner, Grantham, Watson, & Hindman, 2001; Skinner, 2002). Therefore, developing basic math fact fluency may enhance the development of more advanced skills, as well as increasing the probability students will choose to attempt tasks that will help them acquire those skills (Skinner, 1998; Skinner & McCleary, 2010).

Several researchers have recommended that educators use various drill, practice, and feedback procedures to enhance students' ability to solve math facts fluently (Haring & Eaton, 1978; Hasselbring et al., 1987; Skinner, Fletcher, & Henington, 1996; Skinner & Schock, 1995). McCallum, Skinner, and Hutchins (2004) developed the taped-problems (TP) drill procedure to enhance math fact performance by occasioning high rates of accurate academic responding. During TP, students listen to audio-recorded lists of math fact problems and answers, and attempt to write the answer before it is played on the tape. When students do not write the correct answer before the tape plays it, they write the answer after they hear it. As problems and answers are repeated, the response interval (time delay between the problem and answer) gradually increases to encourage students to solve the problem before the answer is provided by the tape. Arranging relatively brief intervals between problems and the intervals between problems and answers (i.e., the response interval) ensures rapid pacing of instruction, thus encouraging higher rates of responding (Carnine, 1976; Skinner, 1998). Brief response intervals also prevent students from applying time-consuming finger-counting strategies that may interfere with the development of fluent responding (McCallum et al., 2004; Poncy, Skinner, & Jaspers, 2007). When students do not respond accurately before the answer is provided, they are required to write the answer after they hear it, thus ensuring that responses are correct (McCallum, Skinner, Turner, & Saecker, 2006). TP procedures also are designed to reduce inaccurate responding. The immediate feedback following each trial decreases the likelihood students will practice incorrect responses over time (Skinner & Smith, 2002). Further, providing initial trials with no response intervals may prevent students from making inaccurate responses from the outset (Browder, Hines, McCarthy, & Fees, 1984; McCurdy, Cundari, & Lentz, 1990).

To date, most TP interventions have been used as individualized remedial strategies for students with various disabilities (Carroll, Skinner, Turner, McCallum, & Woodland, 2006; McCallum et al., 2004; Poncy et al., 2007). TP has also been used as a classwide intervention in second- through fifth-grade classrooms to remediate addition, subtraction, and multiplication deficits (McCallum et al., 2006; McCleary et al., 2011; Windingstad, Skinner, Rowland, Cardin, & Fearington, 2009). Each of these classwide applications was initiated by teachers who had already covered basic-fact objectives, but expressed concern that a specific student, or in some cases many of their students in a particular class, had failed to develop fluent mathematics performance.

Although remediation is important, an equally important goal is to prevent deficits before they occur. Response to intervention (RtI) is a framework that has been adopted by many schools to provide high-quality instruction and interventions that are matched to individual student needs (National Association of State Directors of Special Education, 2006). The basis of RtI is to incorporate a tiered delivery model that increases the intensity of the intervention according to student needs. Within this framework, all students are provided core instruction grounded in evidence-based practice (i.e., "universal" or Tier 1 intervention). Those who fail to progress can be readily identified and provided with targeted interventions (Tier 2) to remediate specific deficits. Highly individualized strategies are reserved for nonresponders to the previous two tiers, thus allowing for the most efficient use of resources. Within the current literature, TP could be viewed as a Tier 2 intervention that targets deficits in fluent math fact performance. However, it also is possible that TP could be successfully used as a Tier 1 intervention, implemented as students are beginning to acquire math skills. Classwide interventions are important in Tier 1 because they arrange effective research-based teaching strategies before a student begins to fail in the general curriculum. Increasing a student's time engaged in active, accurate responding can help gauge the student's progress toward individual and classwide goals. Using classwide data such as those provided during TP can assist teachers in making decisions about struggling students who may need to move on to Tier 2 (Burns, Dean, & Klar, 2004; Fuchs, 2003).

The purpose of the current study was to evaluate the effects of TP in a first grade general education classroom on the initial acquisition of addition-fact skills. In addition to evaluating TP on the acquisition of fluent math performance, we also sought to assess the efficacy of the procedure with a younger group of learners than had been previously studied. In addition, student progress was examined to evaluate whether TP could assist moving students from frustrational to instructional or mastery levels of math performance.

Method

Students and Setting

The study was conducted in a first grade general education classroom at a rural elementary school in the southeastern United States. The class contained 20 students (11 boys, 9 girls), all of whom were Caucasian. None of the students had any identified disabilities, although 4 were referred to a reading specialist for early interventions in reading. At the start of the study, all participants had received instruction in basic addition concepts and mechanics using direct instruction, manipulatives, and worksheets. All the children could complete at least some addition problems, indicating that they understood the basic concept of how to add numbers.

The students' desks were typically arranged in a U shape facing the front of the classroom. Occasionally, students were placed at separate desks facing away from other students. The teacher's desk was on the left side of the room and the tape player was located in the back of the room.

Response Definition and Data Collection

The dependent measure was digits correct per minute (DC/M). A digit was considered correct when it appeared in the correct place for the calculation. For example, if the problem 8 + 4 was scored, the answer 12 would be scored as 2 digits correct because both digits were in the correct place. An answer of 10 or 2 would be scored as 1 digit correct because even though the calculation was incorrect, 1 correct digit was written in the correct place. Skipped problems were scored as incorrect. Assessments (see Materials below) consisted of 45 problems and lasted 30 s, so the number of digits correct was multiplied by 2 to calculate DC/M. Percent correct (PC) was also calculated for each assessment by dividing the number of problems attempted by the number accurately calculated and multiplying by 100.

DC/M for each student was scored independently by a second scorer for 20% of the assessment sheets. The sessions in which interscorer agreement was calculated were randomly selected across the study. Interscorer agreement was calculated by dividing the number of agreements by the number of agreements plus disagreements and then multiplying by 100. Total interscorer agreement for DC/M and percentage correct was 100%.

In addition to measuring student DC/M, we also categorized each student's instructional level (Deno & Mirkin, 1977) across phases. According to Deno and Mirkin's classification for first graders, less than 10 DC/M suggests the student is in the frustrational level, 10 to 19 DC/M suggests the student is in the instructional level, and 20 or more DC/M suggests the student is in the mastery level. If a child's DC/M falls in the frustrational level, that child will probably experience difficulties in mathematics and require additional interventions.

Materials

Three mutually exclusive sets of basic addition problems (digits 1 through 9) were created with 15 problems in each set. Problems without an inverse (e.g., 4 + 4) were randomly assigned to the three groups with 3 of these problems placed in each set. The rest of the problems were randomly assigned to the three sets. Inverted facts (e.g., 7 + 4 and 4 + 7) were not used.

For each problem set (A, B, and C), we created three assessment sheets (for measuring performance), three TP sheets (for students to complete during the TP sessions), and three sprint sheets. Sprint sheets were administered after the TP sessions to provide students with an opportunity to practice independent responding to the problems presented during the session, as research suggests that additional immediate practice after completing TP may enhance performance (Bliss, Skinner, McCallum, Saecker, Rowland, & Brown, 2010). Each assessment and sprint sheet contained the 15 problems for the particular set (A, B, or C) presented vertically with a space for an answer. The 15 problems were presented in random order 3 times on each sheet (for a total of 45 problems per sheet). The TP sheet had the 15 problems in the set organized vertically and repeated in random order 5 times (for a total of 65 problems per sheet).

Procedure

A multiple baseline across sets was used to evaluate the effects of TP on DC/M, percentage correct, and student instructional levels.

Baseline. Students received daily mathematics instruction, which included at least 45 minutes of teacher-guided instruction, worksheets, small group instruction, and use of manipulatives. At the end of each lesson, a 3-page packet consisting of an assessment sheet for each TP set was placed face down on the students' desks. The teacher or experimenter then turned on a tape and instructed the students to follow the instructions provided. The tape prompted the students to write their names on the back of the packet and not turn it over. Next, the tape instructed students to turn their packet over and complete as many problems on the first sheet as they could, following vertically down the page, until the tape told them to stop. Students were instructed to work vertically down the page and to not skip problems. After 30 s elapsed, the tape instructed students to stop and hold their pencils high in the air. If a student was observed writing after they were instructed to put their pencil up, the teacher or experimenter would go to the student's desk and mark the last problem that was completed within the time limit. During the course of the study, cheating (i.e., student continuing to work on assessment sheets after being told to stop) occurred four times and each time the entire class was reminded to hold their pencil up after being told to stop. During the first three sessions, the researcher or teacher stopped the tape after the instructions were read and used a sheet of paper to demonstrate working vertically, reiterated the rules about cheating, and asked the class if they had any questions. The instructions and procedures were repeated on the tape for the subsequent two assessment sheets. The assessment-sheet packets were collected immediately after the third assessment was completed. The tape was not stopped during the 30 s timed assessment.

Taped-problems plus rewards. At the end of the math lesson, students received a packet that contained three assessment sheets (one for each set of problems) followed by a TP sheet and a sprint sheet for the target set. Following completion of the three assessment sheets according to the baseline procedure, a tape was played that provided TP instructions. The students were told to try to write the answer to the problem in the space provided before the tape supplied the answer. This was referred to as "beat the tape." If the students wrote the answer before it was given by the tape, they were instructed to check their answer with the tape. If they did not write the correct answer, they were instructed to write the answer as soon as they heard it on the tape. They were warned, "sometimes I will go fast and sometimes I will go slow, but you should always try to beat the tape." The tape then asked if there were any questions. During the first three days, the tape was then stopped and questions were answered and instructions clarified. The children did not have any questions after the third day.

Within sessions, the tape played the problems as they appeared on the sheet, but the response intervals varied. For the first column, there was no delay between the problem and answer. The second and third columns had 2-s response intervals and the fourth and fifth columns had 1-s response intervals. There was a 1-s delay between the answer and the following problem for all columns. Most of the students worked along with the tape, but occasionally some of the more advanced students were observed working ahead of the tape, completing the problems as fast as they could instead of waiting for the tape to provide the questions and answers. Students were reminded to work with the tape so that they could be sure their answers were correct. If a child wrote an incorrect answer prior to hearing the tape provide the correct answer they were prompted by the experimenter or teacher to cross it out and write the correct answer beside it. The sprint sheet was completed directly after TP. As with the TP sheet, only the targeted set was included in the sprint.

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Twice per week, students were given individual graphs that displayed their scores on the targeted assessment sheets from day to day. Given that the children were not likely to understand the concept of DC/M, the number of problems correctly answered was represented on the graphs. The experimenter showed the students the updated graphs on Tuesdays and Thursdays, and gave students a sticker if they increased their scores from the previous day. For every three star stickers a child earned, he or she would receive a prize (e.g., pencil, eraser, pencil grip). If the student's performance remained the same or decreased from the previous day, the student did not receive a sticker but was encouraged to keep trying and do his or her best. Once Set B began, each graph had two lines (one for Set A and one for Set B). Students were required to increase one line and increase or maintain the other line to earn a star. If either line decreased or

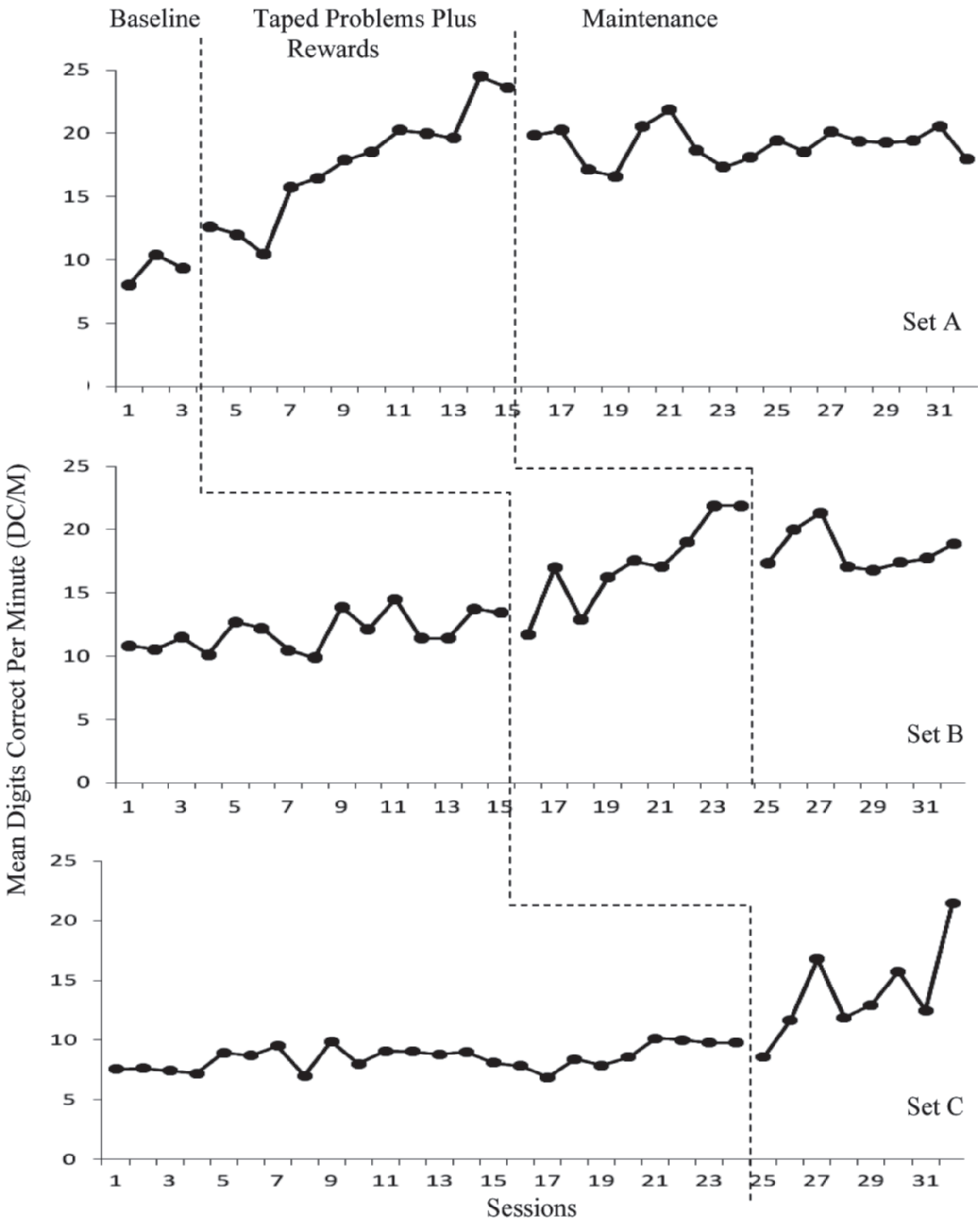

Figure 1. Mean digits correct per minute (DC/M) for all children across baseline, taped problems plus rewards and maintenance conditions.

if they both remained the same, then he or she did not receive a star. For Set C, another line was added and the students had to increase two of the three lines to earn a star.

In addition to individual rewards, a group contingency was used in which the teacher randomly selected five of the targeted assessment sheets each day and averaged the scores. The average was plotted on a group graph on the wall behind the teacher's desk. If the average of the five randomly selected worksheets was equal to or greater than the average from the previous day, the class earned a star. When five stars were earned, the class received a class reward (e.g., time to play with sidewalk chalk).

All procedures were implemented by the experimenter or the teacher. The teacher was trained how to implement the TP intervention during two training sessions without the students present. The teacher then observed while the experimenter conducted the first intervention session. On the second and third sessions, the teacher conducted the intervention with the experimenter present and made no implementation errors. The teacher was then responsible for conducting TP on Mondays, Wednesdays, and Fridays, while the experimenter conducted sessions on Tuesdays and Thursdays. The experimenter was also present each time the phases changed to ensure that procedures were implemented correctly. The experimenter occasionally observed the teacher implementing the intervention to ensure treatment fidelity, although no formal measures were recorded.

Maintenance. After the intervention was withdrawn from Sets A and B, assessment sheets were used daily to collect maintenance data. Maintenance data were not collected for Set C because the school year ended before there was time to obtain these data.

Results

Figure 1 displays the daily class average DC/M across phases and problem sets. During baseline for Set A, the average DC/M was 9 (*SD* = 1) with a slight ascending trend. During TP plus rewards phase, the average DC/M increased to 18 (*SD* = 4) with a steeper ascending trend compared to baseline. During baseline for Set B, the average DC/M was 12 (*SD* = 2) with a slight ascending trend. During the TP plus rewards phase, the average DC/M increased to 17 (*SD* = 4) with a steeper ascending trend compared to baseline. During baseline for Set C, the average DC/M was 9 (*SD* = 1) with no discernable trend. During the TP plus rewards phase, the average DC/M increased to 17 (*SD* = 4) with a steep ascending trend compared to baseline. A similar increase in trend for DC/M was observed for each set when and only when the TP plus rewards condition was in effect, suggesting that changes in performance were a function of the TP plus rewards treatment.

Maintenance data for Sets A and B revealed a slight decrease from the highest TP performance, although DC/M scores were consistently higher in maintenance than in baseline. During the Set A maintenance phase, the average DC/M was 19 (*SD* = 1) and the average DC/M for Set B was 18 (*SD* = 2).

Table 1 displays students' individual gains and instructional levels across phases when all three sets are combined. All students increased their overall DC/M from the baseline to the maintenance phase, ranging from an increase of 1 to 29 DC/M. These data show that some students (e.g., students 4, 11, and 12) showed much greater gain than others (e.g., students 7, 8, 14, and 16). Using Deno and Mirkin's (1977) addition fact fluency criteria for first grade, the average baseline DC/M shows 11 students at a frustrational level and 7 at an instructional level. Average TP DC/M show only 3 students at the frustrational level, 10 at the instructional level, and 5 at mastery. Average maintenance DC/M show 4 students at the frustrational level, 7 at the instructional level, and 7 students at the mastery level.

Conclusions and Implications for Practitioners

Previous researchers have investigated TP as a remedial procedure with older students who had already received fluency training in targeted math facts (Carroll et al., 2006; McCallum et al., 2004; McCallum, Schmitt, Schneider, Rezzetano, & Skinner, 2010; McCallum et al., 2006; McCleary et al., 2011, Poncy et al., 2007; Windingstad et al., 2009). The current study extended this research by using TP to facilitate initial math fact acquisition in first grade students. As the participants had not been exposed to previous structured classroom instruction and/or drill-and-practice designed to enhance fluency with the target addition facts or any math facts, the current results enhance the external validity of TP by demonstrating generality from remediation to instructional application.

There are several components that potentially contribute to the effectiveness of TP interventions. First, students engage in repeated practice via daily assessments, which provide multiple opportunities to respond quickly and accurately (Skinner, Belfiore, Mace, Williams, & Johns, 1997; Skinner & Shapiro, 1989). They also are exposed to the correct answers for each problem multiple times throughout the session. Second, natural reinforcement contingencies are built into the TP intervention. Students who answer quickly and accurately are provided feedback on the tape to confirm the answer they have written, thus reinforcing their correct responses. A unique addition in this study was additional feedback provided through individual and group improvement graphs and the rewards associated with performance improvements. Students were often heard comparing their graphs and making statements such as "only one more until my sticker" and "I bet I can get 14 next time," suggesting that the graphs enhanced the children's motivation to increase their scores. Third, the game-like nature of TP provides an element of competition to "beat the tape," and in this study, to beat one's previous score.

Given the multiple elements employed by TP in general and in the current study in particular, it is difficult to discern which factors were most influential in improving performance. With regard to the current study, we were unable to identify how much of the children's math fact acquisition was due to the reward and feedback procedures and how much was due to TP. In addition, it is difficult to know whether individual or group rewards were more effective, as both were used simultaneously.

Table 1. Individual Student Means, Standard Deviations (SD), Descriptive Level, and Change in Digits Correct Per Minute (DC/M) Across Phases

Student	Baseline (B) Mean *(SD)*	Taped Problem (TP) Mean *(SD)*	Mean DC/M Change B to TP	Maintenance (M) Mean *(SD)*	Mean DC/M Change B to M
1	14 (5), I	17 (6), I	3	21 (6), M	7
2	7 (5), F	14 (6), I	7	15 (6), I	8
3	12 (5), I	17 (7), I	5	16 (4), I	3
4	12 (6), I	37 (16), M	25	41 (14), M	29
5	10 (3), F	14 (4), I	4	16 (6), I	6
6	18 (5), I	24 (7), M	5	26 (8), M	8
7	6 (3), F	7 (4), F	2	8 (4), F	3
8	3 (3), F	6 (3), F	3	5 (2), F	2
9	5 (4), F	7 (5), F	3	12 (4), I	8
10	13 (4), I	18 (8), I	4	25 (6), M	11
11	10 (5), F	20 (12), M	11	28 (6), M	19
12	9 (4), F	24 (12), M	15	34 (12), M	25
13	6 (5), F	12 (7), I	6	15 (7), I	9
14	7 (4), F	10 (7), I	3	8 (5), F	1
15	10 (5), I	19 (9), I	9	18 (7), I	8
16	8 (4), F	11 (6), I	3	10 (4), F	1
17	9 (4), F	13 (5), I	4	13 (4), I	4
18	16 (5), I	26 (7), M	9	28 (5), M	12

Note: F = Frustrational, I = Instructional, M = Mastery level

In future studies, it may be beneficial to separate the reward contingencies and examine the impact of no reward, only individual rewards, only group rewards, and both rewards (McCallum et al., 2010; McCleary et al., 2011). This analysis would assist in identifying the most salient components of the intervention and could potentially streamline the procedure. While it may seem logical that combining procedures would provide the greatest performance improvements, previous research has resulted in inconclusive results when comparing group versus individual reinforcement (e.g., Herman & Tramontana, 1971; Lloyd, Eberhardt, & Drake, 1996; Shapiro, Albright, & Ager, 1986). In the current study, using both feedback/reward contingencies was rather time consuming, as the teacher or experimenter had to calculate and graph both student and class data each day. Therefore, it would be helpful to know the degree to which feedback and reward contingencies are necessary for achieving improved performance.

Future research might also investigate incorporating TP earlier in the school year. A potential limitation of the current study was that it was conducted at the end of the first grade

Table 2. Guidelines for Conducting the Taped-Problems Intervention in a General Education Classroom

1. Create three sets of mutually exclusive basic math facts and create three assessment sheets, three TP sheets, and three sprint sheets for each math fact set, with each sheet randomizing the order of the problems. For the TP sheet, list each problem at least five times in varied order.
2. When making tapes to correspond to the assessment sheets, leave no delay between the problem and answer for problems in the first column. The second and third columns should have 2-s delays and the fourth and fifth columns should have 1-s delays. Leave a 1-s delay between the answer and next problem for all columns.
3. It is easiest to create separate tapes for Set A baseline, Set A TP, Set B TP, and Set C TP. This way, the tape can be rewound when the three versions of each set are completed.
4. Include all directions for the assessment, TP, and sprint sheets on the tape. In the beginning, you can stop the tape to answer any questions before beginning each sheet.
5. Although some teachers allow working ahead, this increases the likelihood students will write incorrect answers. To prevent students from writing incorrect answers while working ahead, you can require all students to stay with the tape.
6. If a student is observed cheating by going over the time limit, mark the last problem that was completed within the time limit.
7. Only collect performance data from the assessment sheets. Digits correct per minute are calculated by adding each digit written in the correct place. If using a 30-s probe, multiply the number of digits correct by 2.
8. Set a mastery criterion to help you determine when to move to the next problem set.
9. If rewards are used, they should be given for improving or maintaining performance on all sets that have been used for TP. This helps students focus on both current and previous sets.
10. If performance graphs are used, display the number of problems correct rather than DC/M.

year, after children had received several months of mathematics instruction. However, at the start of the study, none of the students in the class performed in the mastery level and more than half performed at the frustrational level, indicating that the entire class was still learning the basics of addition. With respect to the RtI framework, it would be interesting to investigate the effects of TP as a Tier 1 intervention earlier in the school year, whereby the effects of the procedure on math fact acquisition (as well computational skills) could be more clearly evaluated. Future research should also employ more stringent procedures for ensuring procedural integrity, as well as assessing teacher and student satisfaction with the procedures via social validity measures.

Although TP appeared to be effective for most students across most sets, the procedure was clearly not effective for some children. It is possible that the high number of problems included in each set negatively affected student performance. In other words, the number of different calculations required per set might have been difficult for lower performing children to master. Therefore, a potential modification to TP would be to target fewer items per set. For example, if problem sets were divided into six groups of 7 or 8 problems, students would be able to complete 10 trials per problem in approximately the same amount of time required 5 trials per problem. This increase in learning trials could potentially enhance fluency development (Skinner & Shapiro, 1989; Skinner et al., 1997). However, it is important to note that exposure to repeated trials might not be sufficient for some students to master math facts and their underlying computations. Some students who struggle with math fact fluency drills such as TP may require direct instruction to understand the mechanics of solving a math problem. For example, Codding, Shiyko, Russo, Birch, Fanning, and Jaspen (2007) suggest that initial level of fluency impacts the effectiveness of time-based interventions. They found that for students whose fluency levels fell in the instructional range, timed interventions such as TP successfully increased performance. For students who began the intervention in the frustrational range, non-timed interventions may increase fluency better.

Despite its limitations, this study contributes to the growing evidence base for taped interventions by applying TP to younger students during the initial acquisition of math facts.

Further, it is a practical and relatively low cost way for teachers to help students acquire basic math facts. Once the assessment, TP, and sprint sheets are created, they can be used multiple times across classes, as can the tapes. Tapes also eliminate the need for the teacher to repeat the instructions each day. The only sheets that need to be graded are the assessment sheets, and calculating DC/M and children's instructional levels is simple using Deno and Mirkin's (1977) guidelines. Table 2 provides a list of guidelines for teachers interested in conducting TP in their classrooms.

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Author Note

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